A survey of amphibians and reptiles in rainforest fragments in the Murugalli – Sheikalmudi estates, Valparai Plateau, Anamalai hills

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nature conservation foundation

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Executive summary

I conducted a preliminary survey of amphibians and reptiles in six forest fragments in the Murugalli-Sheikhalmudi estates on the western edge of Valparai plateau. I used 40 Visual Encounter Surveys during day and night hours over a two month period to record amphibians and reptiles. This revealed the presence of 35 species in these fragments, including 21 species of amphibians and 14 species of reptiles. Thirty species were endemic to the Western Ghats. Four species were Critically Endangered, four Endangered, and two Near Threatened. Additionally, I found 10 species for which there is little information on conservation status. The three largest fragments, viz., Kalyanapandal-Pudukadu, Candura, & Murugalli-Sholayar, had similar species richness. Several unique species were recorded only in one fragment, such as the Critically Endangered frogs *Rhacophorus pseudomalabaricus* in Kalyanapandal-Pudukadu fragment. Even the smallest fragment surveyed supported unique endemic species. Several species specific breeding habitats for amphibians were recorded in these fragments. Habitat characteristics, past management of fragments and seasonality in amphibian and reptile activity seems to have affected the outcome of this survey. Species accumulation curves indicated that the present number of surveys were inadequate for recording all species present in these fragments. Further surveys are necessary to estimate the true number of amphibian and reptile species in forest fragments in the Valparai plateau.

1. Amphibians and reptiles of the Murugalli – Sheikalmudi estates

Within the Murugalli and Sheikalmudi estates of Parry Agro Industries Ltd, Valparai, the present survey of amphibians and reptiles recorded the following 35 species within six rainforest fragments (MS – Murugalli – Sholayar, CAN – Candura, KP – Kalyanapandal-Pudukadu, BB – Black Bridge, MH – Murugalli Hospital, SYK – Sykes; see map)

1. *Duttaphrynus parietalis* (Boulenger, 1882)

Ridged toad

IUCN Redlist status – Near Threatened

Global distribution – Southern Western Ghats

I found this species only in BB fragment, all juveniles on forest floor. The individual pictured is a juvenile, not having the characteristic keratinized ridges on top of the head. (Similar looking *D. beddomii* juveniles have more prominent spines on body, and the inner border of parotoid glands is strongly indented).

2. *Duttaphrynus melanostictus* (Schneider, 1799)

Common Asian toad

IUCN Redlist status – Least Concern

Global distribution – South and southeast Asia

I found this species in all six fragments surveyed. They were more common at the edges of forest fragments.

3. *Fejervarya* cf. *nilagirica* (Jerdon, 1864)

Nilgiri cricket frog

IUCN Redlist status – Not Assessed

Global distribution – Nilgiris & Wayanad, Anamalais (Daniels, 2003).

I recorded this species from MS, CAN, KP, BB, & MH fragments. They inhabit forest clearings with grass growth, especially close to small streams. I found calling males in shallow pools, and puddles. In KP, I found several males calling from puddles created by elephant foot prints.

4. *Fejervarya keralensis* (Dubois, 1981)

Kerala wart frog

IUCN Redlist status – Least Concern

Global distribution – Western Ghats

Recorded from MS, CAN, KP, BB, & SYK fragments. I recorded this species mostly in leaf litter in the forest. I found calling males in shallow puddles in the forest and rock pools bordering streams.

5. *Indirana brachytarsus* (Günther, 1876)

Günther's leaping frog

IUCN Redlist status – Endangered

Global distribution – The Anamalais

I recorded this species from CAN, KP, & BB fragments. During the day, I found them in leaf litter and under logs, whereas at night, they were found near streams on wet rocks and logs. This species seems to lay eggs on wet rocks adjoining streams, where I found tadpoles presumably belonging to this species.

6. *Indirana* cf. *semipalmata* (Boulenger, 1882)

Brown leaping frog

IUCN Redlist status – Least Concern

Global distribution – Western Ghats

I found a single individual during daytime surveys, under a rock in BB fragment that I tentatively assign to this species. This is a fairly widespread species at lower elevations.

7. *Micrixalus nelliyampathi* Biju et al, 2014

Nelliyampathi dancing frog/torrent frog

IUCN Redlist status – Not Assessed

Global distribution – Anamalai and Nelliyampathi Hills

I recorded this species from MS, CAN, & BB fragments. I found males perched on exposed rocks in streams during daytime, and several females away from streams at night, perched on understorey vegetation.

8. *Indosylvirana sreeni* (Biju et al, 2014)

Sreeni's golden-back frog

IUCN Redlist status – Not Assessed

Global distribution – Western Ghats from Siruvani to Gavi; Shevaroy Hills

I recorded this species from all six fragments surveyed. It is the most commonly encountered frog species in the surveyed area. I found them during both day and night surveys. While I saw most individuals on forest floor, or on rocks in fast-flowing streams, several individuals were also seen high up in vegetation (up to 2.5 m above ground).

9. *Indosylvirana doni* (Biju et al, 2014)

Don's golden-back frog

IUCN Redlist status – Not Assessed

Global distribution – The Anamalais

I recorded this species from the larger MS, KP, & CAN fragments. It is less common than as the similar looking Sreeni's golden-backs. Almost all individuals I saw were on vegetation close to slow-flowing streams or swamps.

10. *Clinotarsus curtipes* (Jerdon, 1853)

Bicolored frog

IUCN Redlist status – Near Threatened

Global distribution – Western Ghats (Karnataka, Kerala, & Tamil Nadu)

I recorded this species from three fragments. I found a few calling males in shallow pools close to streams and swamps. Most adults that I saw were on the forest floor during day and night surveys.

11. *Nyctibatrachus acanthodermis* Biju et al, 2011

Spinular night frog

IUCN Redlist status – Not Assessed

Global distribution – Nelliyampathy Hills

I recorded this species from CAN, KP, & BB fragments. These are the first records of this species outside of its type locality (Nelliyampathy). I encountered this species only in streams at night. Most frogs were in water at the edge of streams, clinging to rocks, with just the eyes and nostrils above water. I found a few males calling from under rock crevices in streams.

12. *Nyctibatrachus anamallaiensis* (Myers, 1942)

Anamalai night frog

IUCN Redlist status – Not Assessed, considered synonym of *N. beddomii*, which is Endangered.

Global distribution – Valparai in Anamalais

I found a single individual in MS fragment, in leaf litter on the forest floor. This is one of the smallest frog species in the Western Ghats (snout-vent length 10 mm), known only from Valparai plateau.

13. *Raorchestes griet* (Bossuyt, 2002)

Griet's bush frog

IUCN Redlist status – Critically Endangered

Global distribution – Western Ghats south of Palghat Gap (south to Vagamon)

I found a single individual in leaf litter in MS fragment, away from water bodies. Species of the genus *Raorchestes* are presumably direct developers that do not require water bodies for breeding.

14. *Raorchestes sushili* (Biju & Bossuyt, 2009)

Sushil's bush frog

IUCN Redlist status – Critically Endangered

Global distribution – Known only from Valparai plateau

I recorded this species from all fragments surveyed. This was the most common of the five species of bush frogs recorded during this survey. During daytime, I found them in grass and leaf litter in the forest, while at night males were located calling from understorey bushes.

15. *Raorchestes* aff. *anili* (Biju & Bossuyt, 2006)

Anil's bush frog

IUCN Redlist status – Least Concern

Global distribution – Known from Wayanad, Ponmudi, Parambikulam, & Malakkapara.

I recorded this species only in BB fragment. I found males calling from *Ochlandra* and *Curcuma* clumps, but not in other parts of the fragment. There is no published information on *R. anili* from other areas having such a unique habitat preference. Thus, I tentatively place them in the taxon *R. anili.*

16. *Raorchestes akroparallagi* (Biju & Bossuyt, 2009)

Variable bush frog

IUCN Redlist status – Least Concern

Global distribution – Western Ghats south of Wayanad

I recorded this species from CAN fragment. The single individual was seen calling from a sapling about 1.6 m above ground.

17. *Raorchestes ponmudi* (Biju & Bossuyt, 2005)

Ponmudi bush frog

IUCN Redlist status – Critically Endangered

Global distribution – Western Ghats from Wayanad to Ponmudi.

I recorded this species from CAN, BB, & MH fragments. I also heard calls presumably belonging to this species in KP, but individuals were not seen.

18. *Polypedates pseudocruciger* Das & Ravichandran, 1998

False hour-glass frog

IUCN Redlist status – Least Concern

Global distribution – Southern Western Ghats (Karnataka, Kerala, & Tamil Nadu)

I found a single individual in KP fragment, close to a swampy portion of a stream.

19. *Rhacophorus pseudomalabaricus* Vasudevan & Dutta, 2000

Anamalai gliding frog

IUCN Redlist status – Critically Endangered

Global distribution – Known only from Anamalais and Munnar.

I found this species only in KP fragment. I recorded several breeding individuals around a dammed pool in a stream with overhanging vegetation.

20. *Rhacophorus calcadensis* Ahl, 1927

Kalakkad gliding frog

IUCN Redlist status – Endangered

Global distribution – Western Ghats south of Paghat gap

I found this species only in KP fragment. It occurred in sympatry with breeding *R. pseudomalabaricus* in the same habitat. Several males and females were seen around the dammed pool, and a few pairs in amplexus were also seen.

21. *Uraeotyphlus* cf. *oxyurus* (Duméril & Bibron, 1841)

Pale-throated Caecilian

IUCN Redlist status – Data Deficient

Global distribution – Southern Western Ghats

I located two individuals, one inside CAN fragment, and another in the surrounding tea plantation. I place them in the taxon *U. oxyurus* tentatively as the systematics and taxonomy of this group is still obscure.

22. *Cnemaspis gracilis* (Beddome, 1870)

Slender day gecko

IUCN Redlist status – Least Concern

Global distribution – Nilgiris & Anamalais

I found this species in MS, CAN, KP, & BB fragments. It is arboreal, often encountered on tree trunks. It seems to be active during daytime.

[Note: Identification of *Cnemaspis* spp. are based on the review and re-descriptions given in Manamendra-Arachchi et al. 2007]

23. *Cnemaspis wynadensis* (Beddome, 1870)

Wayanad day gecko

IUCN Redlist status – Endangered

Global distribution – Western Ghats south of Wayanad

I recorded this species in MS, BB, & SYK fragments. It appears to be terrestrial and diurnal or crepuscular. Individuals were found under rocks and logs on forest floor, as well as on boulders.

24. *Ristella guentheri* Boulenger, 1887

Günther's ristella

IUCN Redlist status – Data Deficient

Global distribution – Western Ghats from Palghat gap to Shencottah gap

I recorded a single individual of this diminutive skink from forest floor in SYK fragment.

25. *Eutropis macularia* (Blyth, 1853)

Bronze skink

IUCN Redlist status – Not Assessed

Global distribution – South Asia

I recorded this species from MS, CAN, KP, & SYK fragments. They were found in leaf litter and among rocks on the forest floor. The taxonomic status of populations of this species from Western Ghats is unresolved.

26. *Eutropis carinata* Schneider, 1801

Keeled grass skink

IUCN Redlist status – Least Concern

Global Distribution – South Asia

I had opportunistic encounters of this species in MS, CAN, KP, & SYK fragments. It seems to be a forest edge species, not recorded inside the fragments.

27. *Draco dussumieri* Duméril & Bibron, 1837

Southern flying lizard

IUCN Redlist status – Least Concern

Global distribution - Hills of Peninsular India

I recorded this species from MS, CAN, & KP fragments. This species seems to require large trees as they were always found high on the trunks of rainforest trees.

28. *Calotes ellioti* Günther, 1864

Elliot's forest lizard

IUCN Redlist status – Least Concern

Global distribution – Western Ghats

I recorded this species from CAN, KP, & MH fragments.

29. *Calotes nemoricola* Jerdon, 1853

Nilgiri forest lizard

IUCN Redlist status – Least Concern

Global distribution – Western Ghats south of Kudremukh

I recorded this species from MS fragment, but not as part of the VES surveys. It is likely to be present in more fragments, as it is a canopy living species and likely to be missed in VES surveys.

30. *Lycodon travancoricus* Beddome, 1870

Travancore wolf snake

IUCN Redlist status – Least Concern

Global distribution – Western Ghats, parts of Eastern Ghats

I found a single individual under a log in MS fragment.

31. *Dendrelaphis ashoki* Vogel & van Rooijen, 2011

Ashok's bronzeback

IUCN Redlist status – Least Concern

Global distribution – Western Ghats south of Goa.

I found a single individual in Murugalli-Sholayar fragment. The snake was found in a disturbed, open forest area close to a stream.

32. *Ahaetulla nasuta* Lacépède, 1789

Long-nosed vine snake

IUCN Redlist status – Not Assessed

Global distribution – Peninsular and eastern India, southeast Asia, & Sri Lanka

I recorded this species from Kalyanapandal-Pudukkad, Murugalli-Sholayar, &Murugalli-Hospital fragments. All other than one from MS fragment were juveniles.

33. *Xenochrophis piscator* (Schneider, 1799)

Checkered keelback, Common water snake

IUCN Redlist status – Not Assessed

Global distribution – Throughout south Asia

I recorded this species from Candura and Murugalli-Sholayar fragments. Animals were always found close to streams.

34. *Hebius beddomei* (Günther, 1864)

Beddome's keelback

IUCN Redlist status – Least Concern

Global distribution – Western Ghats

I found a single individual from Murugalli-Hospital fragment.

35. *Hebius monticola* (Jerdon, 1853)

Montane keelback, Hill keelback

IUCN Redlist status – Least Concern

Global distribution – Western Ghats south of Belgaum in Karnataka

I recorded this species in Murugalli-Sholayar and Murugalli-Sykes fragment. Several individuals were seen outside SYK fragment, in the abandoned tea plantation area.

2. Patterns of diversity and abundance of amphibians and reptiles in the rainforest fragments

Introduction

Amphibians and reptiles account for approximately 26% of all vertebrates in the world and more than 50% of the world's tetrapods—a group that includes birds and mammals (Zug et al. 2001). Today, both amphibians and reptiles (together called herpetofauna) are facing global declines, with amphibians considered the most threatened group of vertebrates as many species have been driven extinct or face extinction due to diseases, habitat degradation, climate change, and other factors (AmphibiaWeb 2017). Tropical mountains are hotspots of biodiversity with a large number of species endemic to relatively small areas (Gradstein et al. 2008). The Western Ghats of India, a biodiversity hotspot, has lost most of its original habitat due to land-use conversion related to human activities (Bhupathy et al. 2016). Despite this, recent studies indicate that even in their fragmented and degraded state, patches of remnant forests can sustain biodiversity (Balaji et al. 2014; Anand et al. 2010; Sridhar et al. 2008; Karanth et al. 2016).

The Valparai plateau in the Anamalai Hills has historically lost over 75% of the original tropical rainforest to tea, coffee, and other commercial plantations. Currently, the land-cover in the plateau is a mixture of plantations and remnant forest fragments. There are approximately 80 species of amphibians and more than a hundred species of reptiles known from the Anamalai landscape. According to the *IUCNRedlist of Threatened Species*, 45% of amphibian species from the Anamalais are either Data Deficient or Not Assessed, while 35% have been placed in Critically Endangered or Endangered categories (IUCN, 2017). As most species are known only from original descriptions or anecdotal records, conservation efforts are hampered by lack of fine-scale information on species distribution and abundance within the landscape.

Recent surveys conducted in tea plantations and 14 rainforest fragments in the Valparai plateau recorded 40 species of amphibians and 40 species of reptiles (Kumar et al. 2002; Daniels 2003). The diversity and abundance of amphibians and reptiles are higher in rainforest fragments compared to modified habitats such as plantations (Murali and Raman 2012; Venugopal 2010). In the last decade, there have been significant changes in our understanding of the diversity of herpetofauna in the Western Ghats and many species previously considered as widespread and also occurring in Anamalais are now considered local endemics with small, allopatric distribution ranges (Garg and Biju 2017; Biju and Bossuyt 2009; Biju et al. 2014b; Garg et al. 2017; Biju et al. 2014a, 2011). The number of frog species known from the Western Ghats have increased from 104 in 2001 to 216 in 2017 (Biju 2001; Frost 2017). Considering the

limited studies and the recent taxonomic revisions, it is necessary to conduct further surveys across this region to understand distribution and abundance patterns of herpetofauna.

Methods

Valparai is an undulating plateau (area 220 km^2) located between 800 – 1500 m above sea level (asl) (10.32° N, 76.95° E), in the Anamalai hills in Tamil Nadu, India (Figure 1). The region receives high rainfall, with a mean annual rainfall of over 2800 mm (Rathod and Aruchamy 2010). Natural vegetation of the plateau is mid-elevation tropical wet evergreen forest of the *Cullenia exarillata – Mesua ferrea – Palaquium ellipticum* type (Pascal 1988), most of which were replaced by tea and coffee plantations in the early 20th century. There are numerous rainforest fragments spread across the plateau (Kapoor 2008; Mudappa and Raman 2007; Mudappa et al. 2014). The Anamalai Tiger Reserve lies to the north, east, and south of the plateau, while the Vazhachal Reserved Forest occurs to the west. Valparai has several perennial streams, rivers (mainly, Sholayar and Nirar) and a single large reservoir (Upper Sholayar Dam). Valparai town and many human settlements spread across the plateau contain a resident population of 70,859 people (Census of India 2011), with the highest density of people in the main town.

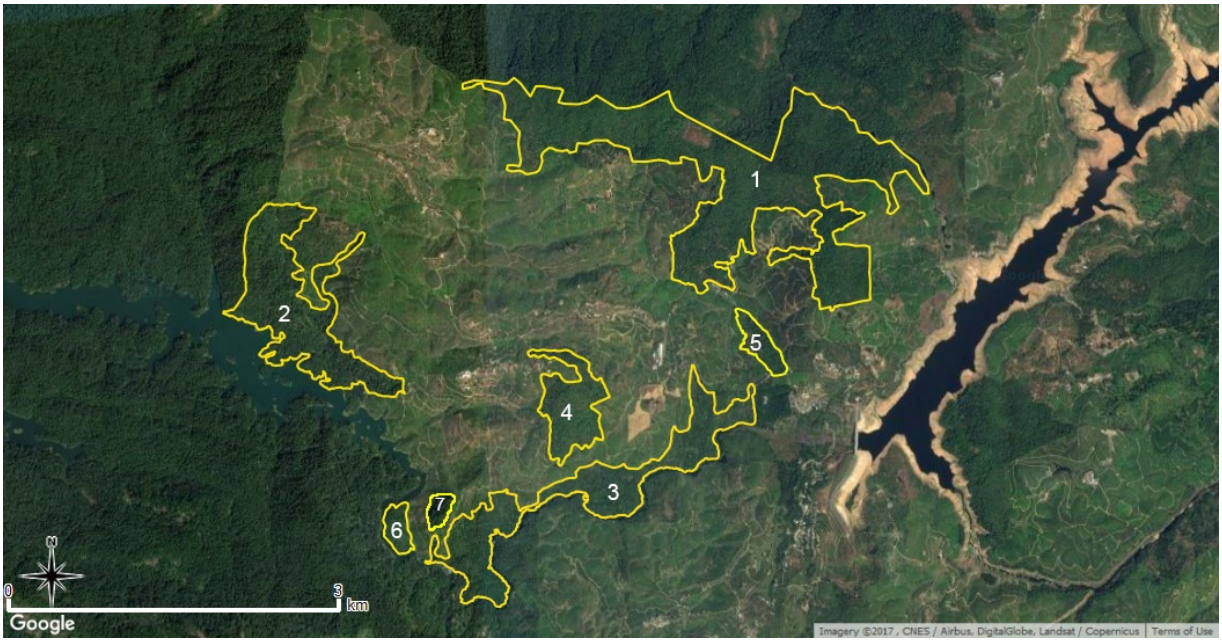

Figure 1. Six fragments surveyed for herpetofauna in the western side of the Valparai plateau; 1: Kalyanapandal-Pudukadu (KP), 2: Candura (CAN), 3: Murugalli Sholayar (MS), 4: Murugalli Hospital (MH), 5: Murugalli Black Bridge (BB), and 6: Murugalli Sykes (MS). 7: Murugalli-Temple was not surveyed.

In this study, we surveyed six rainforest sites of varying sizes, on the western part of the plateau: Candura (CAN – 103.3 ha), Kalyanapandal-Pudukadu (KP – 200 ha), Murugalli-Sholayar (MS – 102 ha), Murugalli-Hospital (MH – 38 ha), Murugalli-Black Bridge (BB – 16 ha), Murugalli-Sykes (SYK – 9 ha), and. Generally, the surveyed areas are located to the west and downstream of Upper Sholayar Dam (Figure1). A seventh fragment (Murugalli-Temple, MT) could not be surveyed due to steep terrain and heavy rainfall during the survey days. Two of the larger rainforest remnants, viz., Kalyanapandal-Pudukadu and Candura, are adjoining contiguous forest, separated only by small clearings. Murugalli-Sholayar, and Sykes fragment are separated from contiguous forest areas by the Sholayar River. All fragments other than Murugalli-Sholayar fragment had perennial streams/river flowing through them or along the edge. The surveyed sites were all between 800 – 1050 m asl.

To record the species richness in the selected fragments, I used time constrained visual encounter surveys (VES) to sample the sites (Crump and Scott Jr 1994; Doan 2003). Each survey was of 1 hr duration during which two observers walked a trail through the sites, searching all potential habitats and recording all individuals sighted. I selected these trails to represent the general habitats and microhabitats present, maximize detections, and based on logistics such as accessibility. Upon sighting an individual, I took detailed photographs showing morphological characteristics. I identified most individuals based on diagnostic morphological characters as described in relevant taxonomic literature, such as Biju et al. (2014b) for frogs of the genus *Indosylvirana*, Biju and Bossuyt (2009 & 2005), Bossuyt (2002), for Rhacophorid frogs currently in the genus *Raorchestes*, Dahanukar et al, (2016) for frogs of the genus *Indirana* and *Sallywalkerana*, Biju et al, (2011) for frogs of the genus *Nyctibatrachus,* Manamendra-Arachchi et al, (2007) for geckos of the genus *Cnemaspis,* and Smith (1935 & 1943) in general for lizards and snakes. Individuals that could not be closely examined and juveniles of some species were assigned to Genus level. I conducted surveys during day (07:00-12:00 h) and night (18:00-19:00 h). Due to logistical difficulties, I could not conduct nighttime surveys in Murugalli-Sholayar and Murugalli Sykes fragments. I carried out these surveys from 9 September to 29 October 2017.

I calculated encounter rates as number of individuals recorded per person-hour of survey effort. To compare the efficacy of day and night time surveys, I compared mean number of individuals and species recorded per survey during day and night surveys (expressed as mean ± standard deviation). To examine the extent of survey completeness, I plotted species accumulation curves using a random addition of samples (number of surveys against number of

species) for each fragment surveyed, using the VEGAN package in program R (R Core Team 2017).

Results

In 40, one-hour-long visual encounter surveys (VES) carried out in the six fragments, I recorded 408 individuals and 34 species of amphibians and reptiles (Table 1, Annexure 1). Additionally, I had opportunistic encounters of the Nilgiri forest lizard *Calotes nemoricola* in MS fragment, bringing the total species richness to 35. This included 12 families and 21 genera. Other than Candura, individual fragments and the pooled data across all sites did not show asymptotes in species accumulation curves, indicating that the number of surveys was inadequate and more species are likely to occur in these fragments (Figure 2).

The mean species richness per survey was similar in daytime and nighttime surveys, but showed greater variation in the former (4.3±1.6 *versus* 5.6±1.7, respectively). More individuals were recorded during nighttime surveys (15.6±9.4 individuals/survey, N =13 surveys) than during daytime surveys (7.7 ±4.4 individuals/survey, N = 27 surveys). With 8 species recorded, the mostly arboreal amphibian family Rhacophoridae was the most species-rich group, followed by the snake family Colubridae (5 species). Despite differences in survey effort, species richness was similar in the three larger sites (Table 1, Figure 3).

Table 1. Visual encounter survey results for six rainforest fragments in the western part of Valparai plateau in the Anamalai hills. Unique species are those that were located only in one forest fragment.

No.	Site	Area (ha)	Number of surveys (Day/Night)	Number of individuals	Species richness	Unique species
1	Kalyanapandal-Pudukadu	200	7 (5/2)	65	17	3
2	Candura	103.3	12 (6/6)	147	20	2
3	Murugalli-Sholayar	102	8 (8/-)	70	21	5
4	Murugalli-Hospital	38	4 (2/2)	25	7	0
5	Murugalli-Black Bridge	16	5 (2/3)	70	15	3
6	Murugalli-Sykes	9	4 (4/-)	33	10	1
	All sites combined		40 (27/13)	408	34	-

Across all sites, *Indosylvirana sreeni* was the most commonly encountered amphibian species, averaging 0.89 individuals/person-hour of survey, while the diminutive diurnal gecko *Cnemaspis* cf. *gracilis* was the most commonly encountered reptile species (Annexure 1). Only

single individuals of six species of amphibians and five species of reptiles were recorded. Several species were recorded only from a single fragment, such as the Critically Endangered tree frog *Rhacophorus pseudomalabaricus* (Figure 5), located only in Kalyanapandal-Pudukadu. The Murugalli-Sholayar fragment had the highest number of such unique species, though no night surveys were carried out in that fragment. Even the smallest fragment surveyed, Murugalli-Sykes, supported unique species such as *Ristella guentheri*.

Based on the IUCN threat status, one species of reptile (*Cnemaspis wayanadensis*) recorded from these fragments was Endangered, 3 species have not been assessed for their conservation status, while one species was Data Deficient (IUCN Redlist, 2017). Among amphibians, 4 species are Critically Endangered (*Rhacophorus pseudomalabaricus*, *Raorchestes ponmudi*, *Raorchestes griet*, and *Raorchestes sushili*) and 3 were Endangered (*Fejervarya nilagirica*, *Indirana brachytarsus*, and *Rhacophorus calcadensis*). Five species of amphibians were 'Not Assessed' for threat levels, while one species was listed as Data Deficient (IUCN Redlist, 2017).

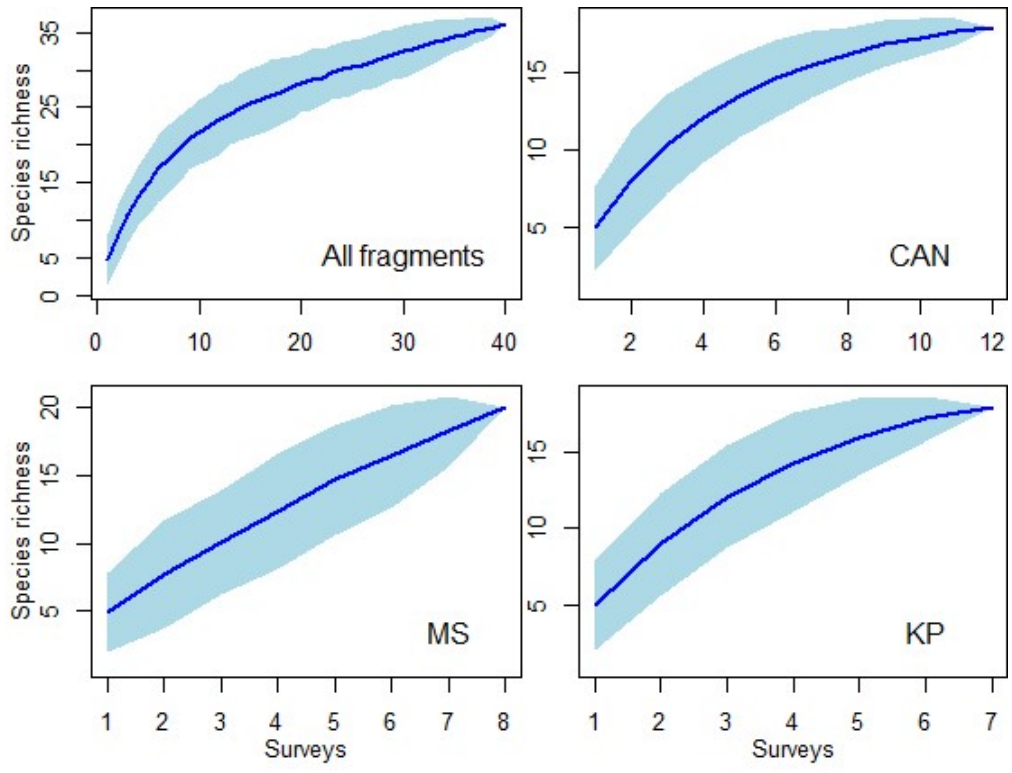

Figure 2. Species accumulation curves for all fragments combined and three largest fragments. Other than Candura (CAN), the curves did not reach asymptotes in Murugalli-Sholayar (MS) and Kalyanapandal-Pudukadu (KP), indicating that more surveys are likely to reveal more species from these fragments. The feather area indicates 95% confidence intervals.

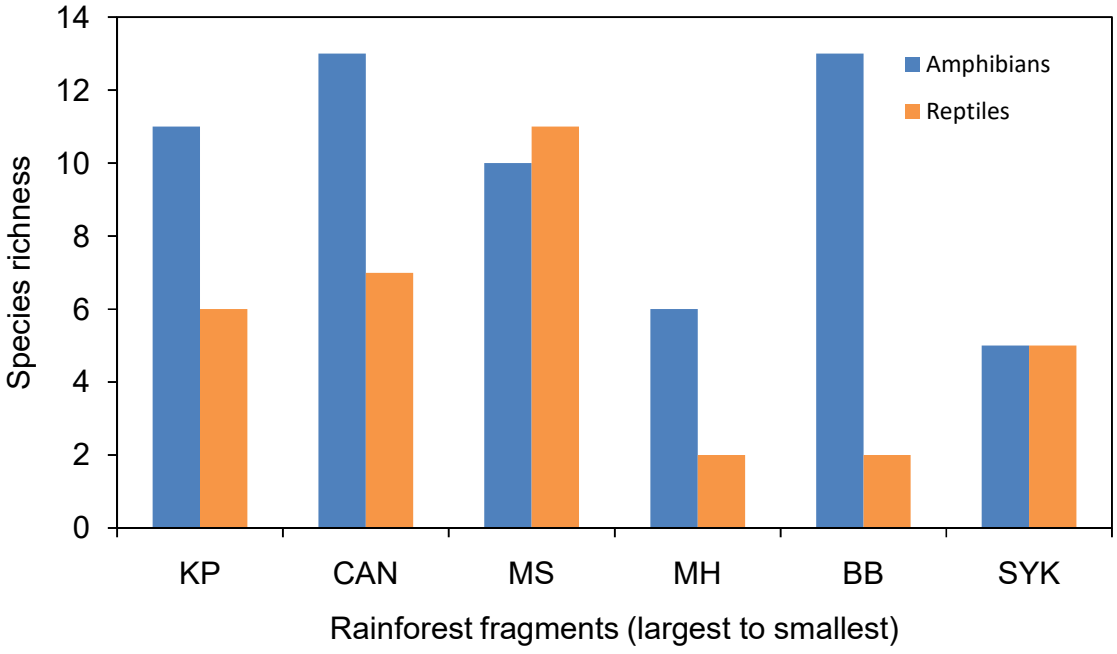

Figure 3. Observed species richness of amphibians and reptiles in rainforest fragments. Black-Bridge fragment had amphibian species richness similar to the larger fragments, probably due to the presence of a perennial stream as well as inadequate sampling of the larger fragments

Figure 5. The Critically Endangered Anamalai gliding frog *Rhacophorus pseudomalabaricus* from Kalyanapandal-Pudukadu fragment. This species was discovered from the Anamalais (Vasudevan & Dutta, 2000), and is known only from a few localities.

Figure 6. Some amphibian breeding habitats/microhabitats from the surveyed area: A – Perennial stream, B – dammed pools with surrounded by vegetation, C – swamps inside rainforest fragments, D – rock pools along the sides of streams, E – wet rock-faces, F – puddles near streams.

Conclusions

The 35 species of amphibians and reptiles recorded from six fragments in this survey is almost certainly an underestimate, as the species accumulation curves indicated. The VES method used may be biased towards amphibians and reptiles that are more visible (Doan 2003). This could explain the absence of several groups such as amphibian species of the genera

Ichthyophis, Uperodon, Sphaerotheca, Nasikabatrachus, Melanobatrachus, besides reptiles belonging to families *Typhlopidae, Gerrhopilidae,* and *Uropeltidae*, all of which are known to have burrowing species that spend most of their life underground and are known to occur in the Anamalai hills. At least two species of shield-tail snakes (Family Uropeltidae) were found dead on the road bordering Black-Bridge fragment on its eastern side (*Uropeltis* cf. *ocellatus*, &*Uropeltis* cf. *grandis*). Also, most surveys were conducted during daytime, and no nighttime surveys could be conducted in two sites. While there was no difference in number of species observed per survey between day and night surveys, this may be misleading as more species could be expected if night survey effort was higher. Several species encountered during day surveys were nocturnal species that had taken refuge under rocks, fallen logs, and leaf litter. Locating these species during the night when they are active allows for better observations of natural history and behavior. The number of individuals found was also higher during night surveys.

Presence of perennial streams and ponds seemed to increase the abundance and species richness of herpetofauna. Murugalli-Hospital fragment, the only site without either of these, had the lowest encounter rates of amphibians and reptiles. Amphibian abundance was generally higher around water bodies (streams, ponds, and marshes). Amphibians are constrained by the diversity and availability of breeding habitats (Figure 6). Most amphibians other than members of the genus *Raorchestes* are dependent on specific types of microhabitats associated with water bodies for breeding: I recorded *Micrixalus nelliyampathi* and *Indosylvirana sreeni* males on rocks in perennial streams (Figure 6A), *Rhacophorus pseudomalabaricus* and *R. calcadensis* breeding in dammed pools with over-hanging vegetation (Figure 6B), *Indosylvirana doni* swamp habitats in streams (Figure 6C), and *Nyctibatrachus acanthodermis* in rock pools in fast flowing streams (Figure 6D). *Indirana* spp. occurred on wet rockfaces and boulders (Figure 6E). I also recorded *Fejervarya nilgirica* and *F. keralensis* males calling from puddles created by elephant footprints (Figure 6F). Identifying these breeding habitats and associated species is important for long-term monitoring of populations of threatened species.

Seasonal activity of amphibians and reptiles is a factor that could have influenced the results of this survey. The surveys were conducted during the retreating monsoon and early north-east monsoon rains. A good proportion of amphibians and reptiles in the Western Ghats are known to be most active during the south-west monsoons (June-August). Therefore, it is likely that more surveys conducted during the beginning of south-west monsoon will find several more species from these forest fragments. Yet another factor that could affect abundance and

species richness of herpetofauna is past management practices, although this survey was not designed to assess these effects.

This short study is the first survey of amphibians and reptiles in these forest fragments. Of the 35 species recorded, 30 species are endemic to the Western Ghats, and a third of the amphibian species recorded were Critically Endangered or Endangered. Further surveys are necessary to estimate the true species richness and distribution of amphibians and reptiles in these fragments. Long-term monitoring programmes are necessary to understand population trends of threatened species that are present in these fragments.

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Annexure 1. The distribution and abundance of amphibians and reptiles in rainforest fragments. The numbers indicate the number of individuals recorded with encounter rates (individuals/person-hour) in brackets. Encounter rates are not given for singletons. A * sign indicates opportunistic records outside VES surveys. A '-' sign indicates that the species was not detected in that fragment during this survey.

Species	All sites (80 person-hours, 408 individuals)	Murugalli-Sholayar (16 person-hours, 70 individuals)	Candura (24 person-hours, 147 individuals)	Kalyanapandal-Pudukadu (12 person-hours, 65 individuals)	Black Bridge (10 person-hours, 70 individuals)	Murugalli-Sykes (8 person-hours, 33 individuals)	Murugalli-Hospital (8 person-hours, 25 individuals)
Common Asian toad *Duttaphrynus melanostictus*	19 (0.24)	1	4 (0.17)	3 (0.25)	3 (0.30)	7 (0.88)	1
Ridged toad *Duttaphrynus parietalis*	2 (0.03)	-	-	-	2 (0.20)	-	-
Kerala wart frog *Fejervarya keralensis*	40 (0.50)	8 (0.50)	11 (0.46)	3 (0.25)	13 (1.30)	5 (0.63)	-
Nilgiri cricket frog *Fejervarya nilagirica*	18 (0.23)	1	6 (0.25)	6 (0.50)	1	-	4 (0.50)
Günther's leaping frog *Indirana brachytarsus*	7 (0.09)	-	4 (0.17)	2 (0.17)	1	-	-
Brown leaping frog *Indirana semipalmata*	1	-	-	-	1	-	-
Bicolored frog *Clinotarsus curtipes*	24 (0.30)	6 (0.38)	-	-	13 (1.30)	5 (0.63)	-
Nelliyampathi dancing frog/torrent frog *Micrixalus nelliyampathi*	19 (0.24)	4 (0.25)	14 (0.58)	-	1	-	-

Species	All sites (80 person-hours, 408 individuals)	Murugalli-Sholayar (16 person-hours, 70 individuals)	Candura (24 person-hours, 147 individuals)	Kalyanapandal-Pudukadu (12 person-hours, 65 individuals)	Black Bridge (10 person-hours, 70 individuals)	Murugalli-Sykes (8 person-hours, 33 individuals)	Murugalli-Hospital (8 person-hours, 25 individuals)
Spinular night frog *Nyctibatrachus acanthodermis*	28 (0.35)	-	18 (0.75)	8 (0.67)	2 (0.20)	-	-
Anamalai night frog *Nyctibatrachus anamallaiensis*	1	1	-	-	-	-	-
Don's golden-back frog *Indosylvirana doni*	14 (0.18)	1	5 (0.21)	7 (0.58)	-	-	-
Sreeni's golden-back frog *Indosylvirana sreeni*	71 (0.89)	20 (1.25)	25 (1.04)	5 (0.42)	13 (1.30)	6 (0.75)	2 (0.25)
Variable bush frog *Raorchestes akroparallagi*	1	-	1	-	-	-	-
Anil's bush frog *Raorchestes* cf. *anili*	8 (0.10)	-	-	-	8 (0.80)	-	-
Griet's bush frog *Raorchestes griet*	1	1	-	-	-	-	-
Ponmudi bush frog *Raorchestes ponmudi*	16 (0.20)	-	11 (0.46)	-	3 (0.30)	-	2 (0.25)
Sushil's bush frog *Raorchestes sushili*	65 (0.81)	8 (0.50)	37 (1.54)	7 (0.58)	3 (0.30)	1	9 (1.13)

Species	All sites (80 person-hours, 408 individuals)	Murugalli-Sholayar (16 person-hours, 70 individuals)	Candura (24 person-hours, 147 individuals)	Kalyanapandal-Pudukadu (12 person-hours, 65 individuals)	Black Bridge (10 person-hours, 70 individuals)	Murugalli-Sykes (8 person-hours, 33 individuals)	Murugalli-Hospital (8 person-hours, 25 individuals)
False hour-glass frog *Polypedates pseudocruciger*	1	-	-	1	-	-	-
Kalakkad gliding frog *Rhacophorus calcadensis*	6 (0.08)	-	-	6 (0.50)	-	-	-
Anamalai gliding frog *Rhacophorus pseudomalabaricus*	4 (0.05)	-	-	4 (0.33)	-	-	-
Pale throated Caecilian *Uraeotyphlys* cf. *oxyurus*	1	-	1	-	-	-	-
Slender day gecko *Cnemaspis* cf. *gracilis*	14 (0.18)	10 (0.63)	2 (0.08)	1	5 (0.50)	-	-
Wayanad day gecko *Cnemaspis waynadensis*	9 (0.11)	1	-	-	1	1	-
Keeled grass skink *Eutropi s carinata*	1	*	*	*	-	1	-
Bronze skink *Eutropis macularia*	10 (0.13)	1	1	3 (0.25)	-	5 (0.63)	-
Günther's Ristella *Ristella guentheri*	1	-	-	-	-	1	-

Species	All sites (80 person-hours, 408 individuals)	Murugalli-Sholayar (16 person-hours, 70 individuals)	Candura (24 person-hours, 147 individuals)	Kalyanapandal-Pudukadu (12 person-hours, 65 individuals)	Black Bridge (10 person-hours, 70 individuals)	Murugalli-Sykes (8 person-hours, 33 individuals)	Murugalli-Hospital (8 person-hours, 25 individuals)
Southern flying lizard *Draco dussumieri*	5 (0.06)	1	2 (0.08)	2 (0.17)	-	-	-
Elliot's forest lizard *Calotes ellioti*	7 (0.09)	-	2 (0.08)	3 (0.25)	-	-	1
Nilgiri forest lizard *Calotes nemoricola*	*	*	-	-	-	-	-
Travancore wolf snake *Lycodon travancoricus*	1	1	-	-	-	-	-
Ashok's bronzeback *Dendrelaphis ashoki*	1	1	-	-	-	-	-
Long-nosed vine snake *Ahaetulla nasuta*	3 (0.04)	1	-	1	-	-	-
Beddome's keelback *Hebius beddomei*	1	-	-	-	-	-	1
Hill keelback *Hebius monticola*	2 (0.03)	1	*	-	-	1	-
Checkered keelback *Xenochrophis piscator*	2 (0.03)	1	1	-	-	-	-